RESEARCH HIGHLIGHT

March 2007

Technical Series 07-106

Evaluation of Water-Efficient Toilet Technologies to Carry Waste in Drainlines

BACKGROUND

No province in Canada currently prohibits the sale and installation of 13- and 20-litre toilet models.[1] As such, Canada is behind most of the developed countries of the world, including the U.S., when it comes to reducing toilet water consumption. This hesitancy appears to stem from two concerns: the perception that efficient toilets do not perform well, and the perception that efficient toilets do not provide enough water to adequately transport waste to the sewer.

The first concern has been addressed through the CMHC-supported Maximum Performance (MaP) Testing of Toilets program. To date the MaP program has rated the flushing performance of more than 300 toilet models and identified more than 200 models that are almost certain to exceed customer expectations for performance. Updated MaP reports are posted on the Canada Water and Wastewater Association website: cwwa.ca/home_e.asp.

The second concern regarding the ability of water-efficient toilets to transport waste to the sewer has been addressed with the completion of this study.

STUDY DETAILS

The test regime for this study involved physically measuring the effectiveness of nine different types of water-efficient toilets to transport waste through both 75 mm and 100 mm pipes [2] installed at different slopes and under various conditions. Because the intent of this project was to evaluate different flushing systems and not specific toilet models, model names have been purposely omitted from this report.

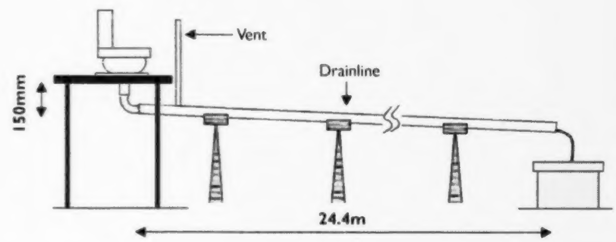

Figure 1 Laboratory Setup

Types of Flushing Systems Tested

1. Gravity – washdown (commonly used in Europe and Australia)
2. Gravity – 75 mm flush valve/flapper
3. Gravity – tipping bucket
4. Gravity – siphon jet in trapway
5. Gravity – siphon jet in sump of bowl
6. Gravity – rim jet
7. Gravity – vacuum-assist
8. Pressure-assist – 6.0 litres per flush (Lpf)[3]
9. Pressure-assist – 3.8 Lpf

1 The Province of Ontario and some individual municipalities do require 6-litre toilets to be installed in new construction.

2 Drains serving a single toilet must be at least 75mm. Drains serving three or more toilets must be at least 100mm.

3 Static supply pressure to the test rig was set at 50 pounds per square inch (psi).

As well as different types of flushing systems, several other variables were evaluated to assess how they impacted drainline carry distance. It was expected that some of these variables would have a greater impact than others.

Variables Tested

1. flush volume,[4]
2. slope of drain piping (2-per cent, 1-per cent, 0-per cent)
3. diameter of piping (75 mm and 100 mm),
4. mass of waste flushed,
5. additional carry distance after second flush,
6. venting vs. no venting, and
7. 'dips and sags' in drainage piping

Best Case/Worse Case Conditions

The focus of this study was to assess the ability of water-efficient toilets to transport waste through drainlines and not to assess the drainlines themselves. As such, new clear plastic piping was used to facilitate observations. The drainlines were installed straight and true,[5] and connected with pipe couplings that offered minimal interference with internal flow. The physical piping setup used in this study, therefore, represents the 'best-case scenario.'

In a typical residential installation, drainlines carry flow not only from toilets but also from sinks, showers, clothes washers, dishwashers, etc. To be conservative this study was completed with no ancillary flows, i.e., under the 'worst case scenario.'

Realistic Media and Procedure = Realistic Results

To obtain realistic and indicative test results it is necessary to use realistic test media and a realistic test protocol. The test media, or "waste" used in this study consisted of four 50 g test specimens (200 g total) of extruded soybean paste [6] plus four balls of loosely crumpled toilet paper; the soybean paste used in this study has physical properties similar to that of human waste. Like human waste, the soybean paste was free to break up into smaller pieces and either spread out or 'clump up' in a ball as it is moved through the drainline. In some test runs the media cleared the entire length of piping; in other tests the media came to rest within the piping.

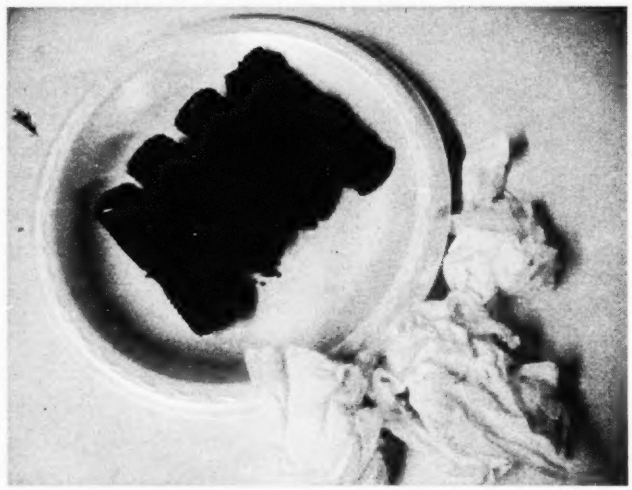

Figure 3 Extruded soybean paste, toilet paper

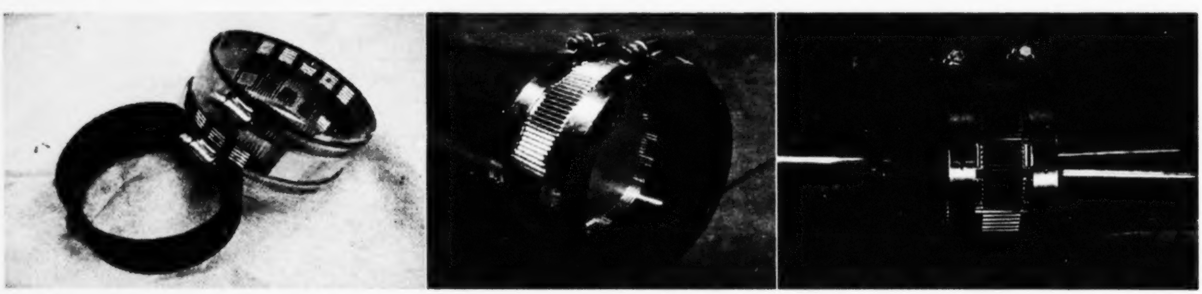

Figure 2 Plastic pipe and coupling

4 The flush volumes of pressure-assisted fixtures could not be adjusted.

5 A laser level was used to ensure accurate pipe slopes; a string-line was used to ensure piping was straight.

6 Medical studies indicate the mass of the average bowel movement in North America is about 130g. A mass of 200g was used in the study to ensure that the results were somewhat conservative.

Results

Effect of different flushing systems

To establish a relative ranking of how well the different flushing systems were able to transport waste, the carry distance of each flushing system was compared to the average carry distance of all models tested.[7] The 6L pressure-assisted model ranked the highest with carry distances approximately 30 per cent greater than of the average of the other flushing systems, while the washdown and vacuum-assisted models had carry distances approximately 30 per cent less than average.

It is interesting to note that even though toilets with significantly different flushing systems were tested, all 6L models carried waste to within ±30 per cent of the average distance.

Test results also indicated that there does not appear to be any correlation between a toilet's ability to clear waste from the bowl and its ability to transport waste through the drainline, i.e., toilet models that offer a high level of flushing performance when MaP tested are not necessarily the same models that transport waste further in the drainline.

Figure 4 compares the different flushing systems. Each system is compared to the average of all 6L systems to provide a relative ranking system.

Effect of Flush Volume

As expected there is a positive correlation between flush volume and drainline carry distance–higher flush volumes carry waste further in the drain. As an example, waste was transported an average of 2.7 m further when the flush volume was increased from six litres to seven litres for drains installed at a one per cent slope, and 4.5 m further in pipes installed at a two per cent slope.

Effect of Drainline Slope

As expected there is a positive correlation between slope and drainline carry distance–steeper slopes carry waste further in the drain. As an example, six litres of water could flush 200 g of waste through a 75 mm drainline an average of 6 m when the pipe was installed at a zero per cent slope, 10 m when the pipe was installed with a one per cent slope, and 22 m when the pipe was installed at a two per cent slope.

7 The 3.8-L pressure-assist model was not included when calculating the average because of its lower flush volume.

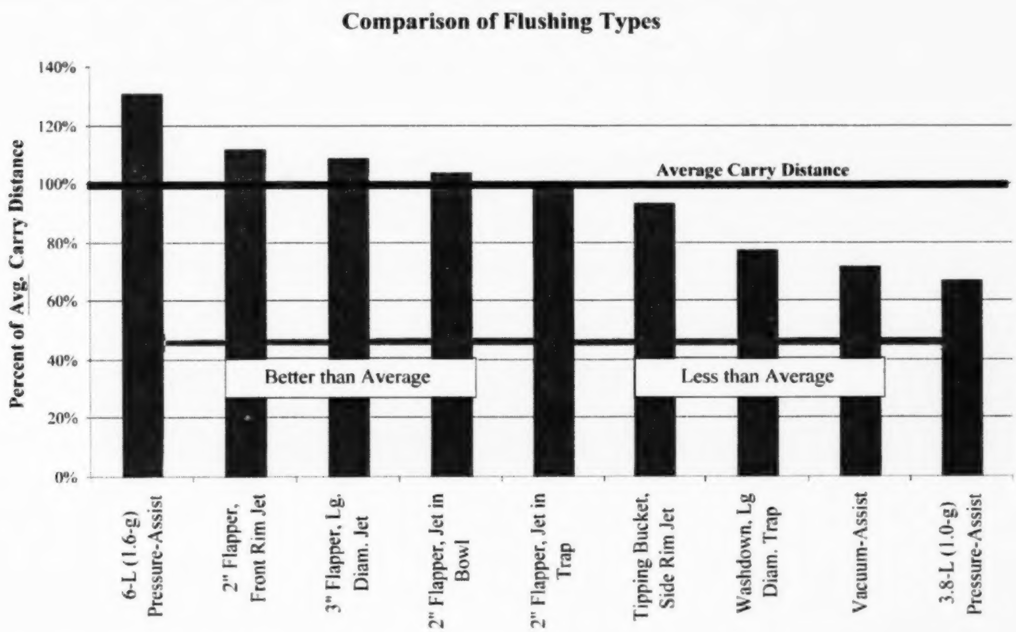

Figure 4 Comparative Ranking of Flushing Systems

Effect of Drainline Diameter

As expected, there is an inverse correlation between pipe diameter and drainline carry distance, at least for the 75 mm and 100 mm diameter pipes tested as part of this project. In larger diameter pipes the flow of water and waste is allowed to spread out further, thereby reducing the velocity of the flow and, consequently, reducing the carry distance.

Effect of Mass Loading

As expected, there is an inverse correlation between mass loading and drainline carry distance. Carry distance *decreased* by approximately 1.4 m for every additional 100 g of mass added to the test loading for pipes sloped at one percent and by approximately 1.6 m for pipes sloped at two per cent.

Effect of Next Flush

It has been estimated that only 20 to 30 per cent of residential toilet flushes contain solids other than toilet paper. As expected, a second 'liquid only' flush pushed the waste further along the drain. In real-world conditions the timing of a second flush would be somewhat variable, i.e., it may occur soon after an initial solids flushing or not for a day or more. In this study, however, it was not practical to wait for long periods of time between flushes. As such, the extent of the additional carry distance provided by a second liquid-only flush has not been quantified.

Effect of Venting

There did not appear to be a noticeable correlation between venting and drainline carry under the conditions established for this project.[8] This result, however, is not meant to imply that similar results would be found under all field conditions.

Effect of 'Dips and Sags' in Drainage Piping

As expected, carry distance was reduced when 'dips and sags' were introduced in the drainline. Although this aspect of the testing program was not exhaustive (there is an unlimited number of possible variables when evaluating dips, sags, bends, bumps, buildup within the pipe, rough pipe walls, etc.), it was intended to verify that installing drainage piping that is not straight and true can lead to reductions in carry distances.

Minimum expected carry distance ULF Toilets

Most concerns expressed by the public involve the ability of efficient toilets to carry solid waste to the sewer in residential installations. These concerns may be somewhat misplaced as a toilet flush would only typically be expected to transport waste a short distance through building drains until the flow is augmented with various supplemental flows from showers, baths, clothes washers, etc. Rarely would a toilet flush alone be expected to transport waste to the municipal sewer or a septic tank.

Under the conditions described for this study, efficient toilets were able to transport test media approximately 20 m in a 75 mm drainline installed at a two percent slope *without any supplemental flows.* Only in rare cases would residential requirements exceed this distance.

Commercial installations, however, are far more likely to have long drainlines, larger diameter pipes, and little in the way of supplemental flows. As such, there may be a greater potential for waste transportation problems to occur in commercial vs. residential applications.

Table 1 summarizes the average distance achieved by the nine test fixtures. These values reflect the installation conditions outlined in this report.

8 This agrees with the results of a 2004 drainline carry project completed by Texas A&M University.

Table 1 Waste Carry Distances (at 200 g load)[9]

Fixture Type	Carry Distances, m			
	75 mm diameter		100 mm diameter	
	1% slope	2% slope	1% slope	2% slope
Pressure Assist – 6.0 Lpf	13.6	> 24.4	10.6	19.5
Gravity – Rim Jet	11.8	> 24.4	8.8	16.6
Gravity – 75 mm Flush Valve	10.6	> 24.4	9.2	15.7
Gravity – Jet in Sump of Bowl	11.3	> 24.4	7.8	16.3
Gravity – Jet in Trapway	11.3	> 24.4	8.7	11.8
Gravity – Tipping Bucket	9.1	> 24.4	7.3	14.2
Gravity – Washdown	8.8	19.4	6.4	10.3
Gravity – Vacuum-Assist	11.3	12.7	7.1	9.8
Pressure-Assist – 3.8 Lpf	11.3	12.8	6.7	9.2

CONCLUSIONS

75 mm drains installed at two per cent slope (typical of residential installation): Under study conditions efficient toilets transported 200 g of test media between 16 m and 27 m, depending on type of flushing system.

100 mm piping installed at one per cent slope (typical of commercial installation): Under study conditions efficient toilets transported 200 g of test media between 6 m and 10.5 m, depending on type of flushing system.

The drainline carry provided by the current generation of water-efficient toilets is more than sufficient to meet the needs of residential applications, provided that the piping is installed properly and is free from blockages, even with no supplemental flows from showers, baths, or clothes washers. Installations with extremely long drainage distances, e.g., shopping malls or industrial sites, however, may require evaluation on a site-by site basis, especially if no supplemental flows are available.[10]

AUTHOR'S NOTE

Some sources have claimed that the use of efficient toilets will reduce flow rates within the municipal sewer system to such a degree as to cause widespread problems with sewer blockages. Sewers are designed to operate properly within a very wide range of flow rates. For example, sewers in a new subdivision serve their purpose as well when only the first few homes in the neighborhood are occupied and contributing to flows as when all of the homes in the subdivision are occupied. There are no documented cases of efficient toilets reducing flows enough to cause sewer blockages; therefore, this study focuses only on waste transport concerns within the building drainage system.

9 Total length of test piping was 24.4 m.

10 Pipes connecting commercial sites to sewers may be 6" diameter or larger, further reducing carry distances.

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Housing Research at CMHC

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